



# GATE 2020

## Solutions

BY

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# Electrical Engineering

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## Aptitude

01. Select the word that fits the analogy:

Do : Undo :: Trust : \_\_\_\_\_

- (a) Entrust (b) Untrust  
(c) Distrust (d) Intrust

**Ans: (c)**

**Solution:**

Distrust means 'lack of trust'.

02. Non-performing Assets (NPAs) of a bank in India is defined as an asset, which remains unpaid by a borrower for a certain period of time in terms of interest, principal, or both. Reserve Bank of India (RBI) has changed the definition of NPA thrice during 1993-2004, in terms of the holding period of loans. The holding period was reduced by one quarter each time. In 1993, the holding period was reduced by one quarter each time. In 1993, the holding period was four quarters (360 days).

Based on the above paragraph, the holding period of loans in 2004 after the third revision was \_\_\_\_\_ days.

- (a) 45 (b) 180  
(c) 90 (d) 135

**Ans: (c)**

**Solution:**

After third revision,

Number of days in holding period =  $(4 - 3)$  quarters = 1 quarter

$$= \frac{360}{4} \text{ days} = 90 \text{ days}$$

03. In four-digit integer numbers from 1001 to 9999, the digit group "37" (in the same sequence) appears \_\_\_\_\_ times.

- (a) 279 (b) 280  
(c) 299 (d) 270

**Ans: (b)**

**Solution:**

Number of numbers of the form 37

$$= {}^{10}C_1 \times {}^{10}C_1 = 100$$

Number of numbers of the form 37

$$= {}^9C_1 \times {}^{10}C_1 = 90$$

Number of numbers of the form 37

$$= {}^9C_1 \times {}^{10}C_1 = 90$$

Hence, total number of times 37 appears

$$= 100 + 90 + 90 = 280 \text{ times}$$

04. People were prohibited \_\_\_\_\_ their vehicles near the entrance of the main administrative building.

- (a) to park (b) from parking  
(c) to have parked (d) parking

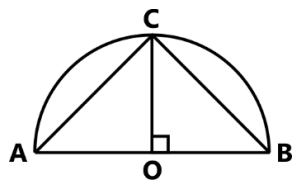
**Ans: (b)**

**Solution:**

One is prohibited from doing a work.



05. Given a semicircle with O as the centre, as shown in the figure, the ratio  $\frac{\overline{AC} + \overline{CB}}{\overline{AB}}$  is \_\_\_\_\_ ,  
where  $\overline{AC}$  ,  $\overline{CB}$  and  $\overline{AB}$  are chords.



- (a)  $\sqrt{3}$  (b) 3  
(c)  $\sqrt{2}$  (d) 2

**Ans: (c)**

**Solution:**

$$AO = OC = OB = r \text{ (radius)}$$

By Pythagoras theorem,

$$AC^2 = r^2 + r^2 \text{ \& } BC^2 = r^2 + r^2$$

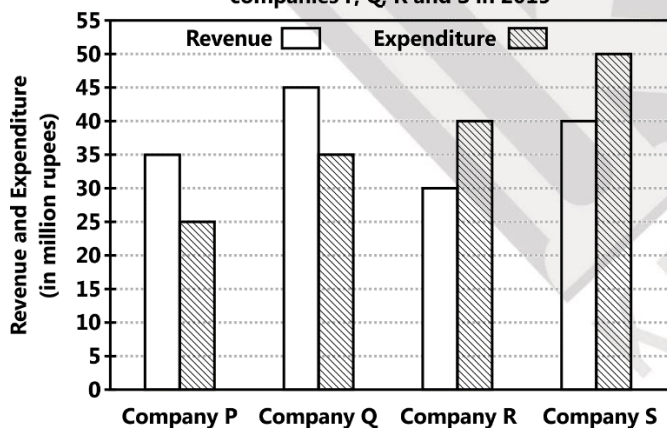
$$\text{Hence, } AC = \sqrt{2}r, BC = \sqrt{2}r$$

$$AB = AO + OB = 2r$$

$$\therefore \frac{\overline{AC} + \overline{BC}}{\overline{AB}} = \frac{2\sqrt{2}r}{2r} = \sqrt{2}$$

06. The revenue and expenditure of four different companies P, Q, R and S in 2015 are shown in the figure. If the revenue of company Q in 2015 was 20% more than that in 2014, and company Q had earned a profit of 10% on expenditure in 2014, then its expenditure (in million rupees) in 2014 was \_\_\_\_\_ .

Revenue and Expenditure (in million rupees) of four companies P, Q, R and S in 2015



- (a) 35.1 (b) 32.7  
(c) 34.1 (d) 33.7

**Ans: (c)**

**Solution:**

$$\text{Revenue of Q in 2015} = 1.2 \text{ (revenue in 2014)}$$

$$\text{Revenue in 2014} = \frac{45}{1.2}$$

Since profit was 10% on expenditure in 2014



$$\frac{\text{revenue} - \text{expenditure}}{\text{expenditure}} = 0.1$$

$$\text{Expenditure} = \frac{\text{revenue}}{1.1} = \frac{45 / 1.2}{1.1} = 34.1$$

07. If P, Q, R, S are four individuals, how many teams of size exceeding one can be formed, with Q as a member?

- (a) 8 (b) 5  
(c) 7 (d) 6

**Ans: (c)**

**Solution:**

When there are two members with Q as a member,

No. of teams = 3

For three members,

No. of teams =  ${}^3C_2 = 3$

For four members,

No. of team =  ${}^3C_3 = 1$

Since, the no. of members must exceed one,

Total no. of teams =  $3 + 3 + 1 = 7$

08. This book, including all its chapters, \_\_\_\_\_ interesting. The students as well as the instructor \_\_\_\_\_ in agreement about it.

- (a) were, was (b) is, are  
(c) are, are (d) is, was

**Ans: (b)**

**Solution:**

With 'book', singular verb will be used.

Hence it should be 'is' in the first sentence.

While using 'as well as', verb agrees with the first subject.

Hence, 'are' is to be used as first subject is 'the students'.

09. Select the next element of the series: Z, WV, RQP, \_\_\_\_\_

- (a) KJIH (b) JIHG  
(c) NMLK (d) LKJI

**Ans: (a)**

**Solution:**

Difference between last letter of preceding word and first letter of following word, is equal to the number of letters in the following word.

Hence, After RQP, it will be

KJIH as

Between P & K, there are L, M, N, O  
4 letters

10. Stock markets \_\_\_\_\_ at the news of the coup.

- (a) Plugged (b) Poised  
(c) Probed (d) Plunged

**Ans: (d)**

**Solution:**

To plunged means to fall suddenly.

## Technical

**01.** Out of the following options, the most relevant information needed to specify the real power (P) at the PV buses in a load flow analysis is

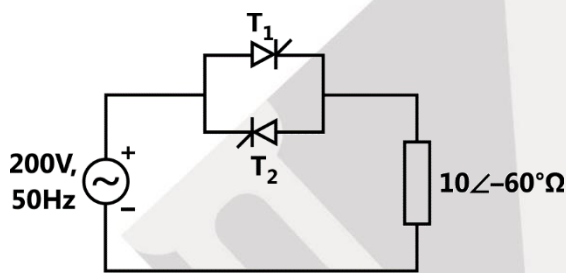
- (a) Rated power output of the generator
- (b) Rated voltage of the generator
- (c) Solution of economic load dispatch
- (4) Base power of the generator

**Ans: (c)**

**Solution:**

Real power P of pv buses is determined by the solution of economic load dispatch.

**02.** Thyristor  $T_1$  is triggered at an angle  $\alpha$  (in degree), and  $T_2$  at angle  $180^\circ + \alpha$ , in each cycle of the sinusoidal input voltage. Assume both thyristors to be ideal. To control load power over the range 0 to 2 kW, the minimum range of variation in  $\alpha$  is:



- (a)  $0^\circ$  to  $120^\circ$
- (b)  $60^\circ$  to  $180^\circ$
- (c)  $60^\circ$  to  $120^\circ$
- (d)  $0^\circ$  to  $60^\circ$

**Ans: (b)**

**Solution:**

$$\text{Apparent power of load} = \frac{V_o^2(\text{rms})}{Z}$$

$$\text{Real power of load} = \frac{V_o^2(\text{rms})}{Z} \cos \phi$$

$$P = \frac{V_o^2(\text{rms})}{10} \cos 60$$

$$P = \frac{V_o^2(\text{rms})}{20}$$

$$\text{If } P = 0 \text{ kW } V_o(\text{rms}) = 0$$

$$\text{If } P = 2 \text{ kW } V_o(\text{rms}) = \sqrt{20 \times 2000} = 200 \text{ V}$$

$V_o(\text{rms})$  in this case is same as source voltage for which  $\alpha \leq \phi$

Which means  $\alpha \leq 60^\circ$

For  $V_o(\text{rms}) = 0$ , SCR must not conduct & hence  $\alpha = 180^\circ$

03.  $X_R$  and  $X_A$  are, respectively, the rms and average values of  $x(t) = x(t-T)$ , and similarly,  $y_R$  and  $y_A$  are, respectively, the rms and average values of  $y(t) = kx(t)$ .  $k, T$  are independent of  $t$ . Which of the following is true?

- (a)  $Y_A \neq kX_A; y_R = kX_R$  (b)  $Y_A = kX_A; y_R = kX_R$   
(c)  $Y_A \neq kX_A; y_R \neq kX_R$  (d)  $Y_A = kX_A; y_R \neq kX_R$

**Ans: (b) or (d)**

**Solution:**

$$y_A = \frac{1}{T} \int_{(T)} kx(t) dt = k \times \frac{1}{T} \int_{(T)} x(t) dt = k X_A$$

$$y_A = \text{Average of } y(t)$$

$$X_A = \text{Average of } x(t)$$

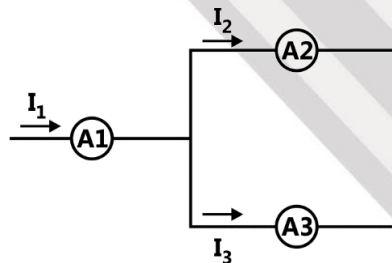
$$y = kx$$

$$y_R = \sqrt{\frac{1}{T} \int_{(T)} [kx(t)]^2 dt} = \sqrt{k^2 \times \frac{1}{T} \int_{(T)} x^2(t) dt} = k \sqrt{\frac{1}{T} \int_{(T)} x^2(t) dt} = kX_R$$

$$Y_R = \text{RMS of } y(t)$$

$$X_R = \text{RMS of } x(t)$$

04. Currents through ammeters A2 and A3 in the figure are  $1\angle 10^\circ$  and  $1\angle 70^\circ$ , respectively. The reading of the ammeter A1 (rounded off to 3 decimal places) is \_\_\_\_\_ A.



**Ans: 1.7 to 1.8**

**Solution:**

Applying KCL,

$$i_{A1} = 1\angle 10^\circ + 1\angle 70^\circ$$

$$|i_{A1}| = \sqrt{1^2 + 1^2 + 2 \times 1 \times 1 \times \cos(70 - 10)}$$

$$|i_{A1}| = \sqrt{3}$$

05. Consider a signal  $x[n] = \begin{cases} \frac{1}{2} & n \geq 0 \\ 0 & n < 0 \end{cases}$ . The z-transform of  $x[n-k]$ ,  $k > 0$

is  $\frac{z^{-k}}{1 - \frac{1}{2}z^{-1}}$  with region of convergence being

- (a)  $|z| < 1/2$  (b)  $|z| > 2$   
(c)  $|z| > 1/2$  (d)  $|z| < 2$

**Ans: (c)****Solution:**

$$X(z) = \frac{z^k}{1 - \frac{1}{2}z^{-1}}$$

Pole is at  $z = \frac{1}{2}$

For a right sided signal, the ROC lies outside the region with largest pole as the radius.

$\therefore$  ROC is  $|z| > \frac{1}{2}$

**06.** A single 50 Hz synchronous generator on droop control was delivering 100 MW power to a system. Due to increase in load, generator power had to be increased by 10 MW, as a result of which, system frequency dropped to 49.75 Hz. further condition, the power in MW supplied by the generator is \_\_\_\_\_. (rounded off to 2 decimal places).

**Ans: 130****Solution:**

Let  $f = aP + b$

where  $a$  &  $b$  are constants.

Now,

when  $P = 100$  MW,  $f = 50$  Hz

when  $P = 110$  MW,  $f = 49.75$  Hz

$$\therefore 50 = 100a + b \quad \dots (i)$$

$$49.75 = 110a + b \quad \dots (ii)$$

Solving the above 2 equations,

$$10a = 49.75 - 50$$

$$a = -0.025$$

Putting  $a = -0.025$  in equation (i),

$$50 = -100 \times 0.025 + b$$

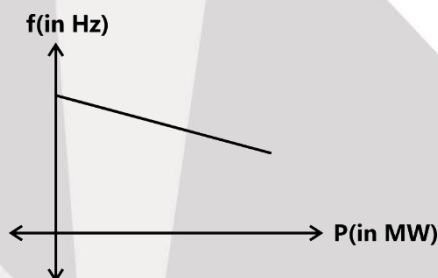
$$b = 52.5$$

Now,

for  $f = 49.25$  Hz,

$$49.25 = -0.025 \times P + 52.5$$

$$P = 130 \text{ MW}$$



**07.** Consider the initial value problem below. The value of  $y$  at  $x = \ln 2$ , (rounded off to 3 decimal places) is \_\_\_\_\_.

$$\frac{dy}{dx} = 2x - y, \quad y(0) = 1$$

**Ans: 0.80 to 0.95****Solution:**

$$\frac{dy}{dx} = 2x - y$$

$$\frac{dy}{dx} + y = 2x$$

Which is of the form,

$$\frac{dy}{dx} + Py = Q$$

where P & Q are functions of x

$$IF = e^{\int P dx} = e^{\int dx} = e^x$$

$$P = 1$$

$$Q = 2x$$

Now,

$$y \cdot IF = \int Q(IF) dx$$

$$ye^x = \int 2xe^x dx + C$$

$$ye^x = 2(x-1)e^x + C$$

$$y(0) = 1$$

$$1 = -2 + C$$

$$C = 3$$

$$\therefore ye^x = 2(x-1)e^x + 3$$

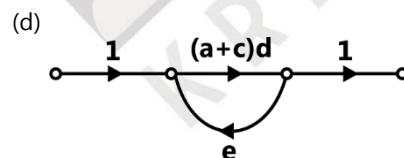
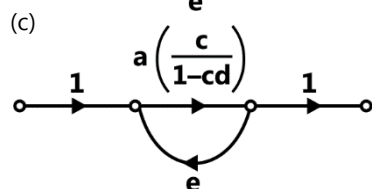
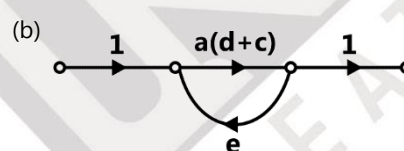
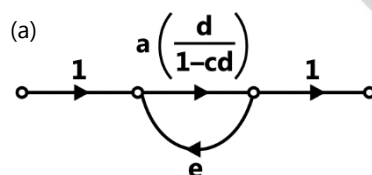
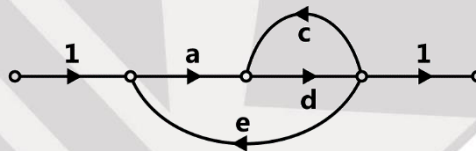
For  $x = \ln 2$ ,

$$y e^{\ln 2} = 2(\ln 2 - 1)e^{\ln 2} + 3$$

$$2y = 2(\ln 2 - 1) \times 2 + 3$$

$$y = 0.886$$

08. Which of the options is an equivalent representation of the signal flow graph shown here?



Ans: (a)

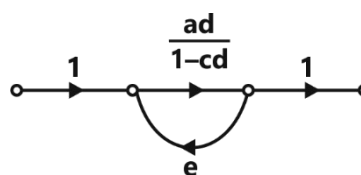
Solution:

$$\text{Gain of closed loop} = \frac{G}{1 - GH} = \frac{d}{1 - cd}$$

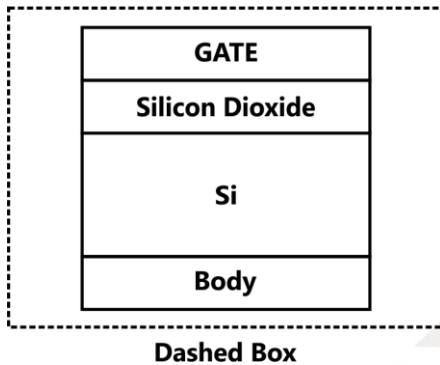
Since, a is cascaded with closed loop

$$\text{gain} = \frac{ad}{1 - cd}$$

Equivalent system



09. The cross-section of a metal-oxide-semiconductor structure is shown schematically. Starting from an uncharged condition, a bias of +3V is applied to the gate contact with respect to the body contact. The charge inside the silicon dioxide layer is then measured to be +Q. The total charge contained within the dashed box shown, upon application of bias, expressed as a multiple of Q (absolute value in Coulombs, rounded off to the nearest integer) is \_\_\_\_\_.



**Ans: 0**

**Solution:**

This is an example of MOS capacitor across which a bias of 3V is applied.

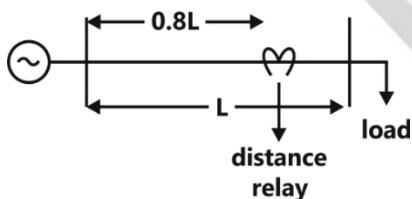
Since plates of capacitor carry equal & opposite charges & hence net charge = 0

10. A lossless transmission line with 0.2 pu reactance per phase uniformly distributed along the length of the line, connecting a generator bus to a load bus, is protected up to 80% of its length by a distance relay placed at the generator bus. The generator terminal voltage is 1 pu. There is no generation at the load bus. The threshold pu current for operation of the distance relay for a solid three phase-to-ground fault on the transmission line is closest to:

- (a) 3.61 (b) 5.00  
(c) 6.25 (d) 1.00

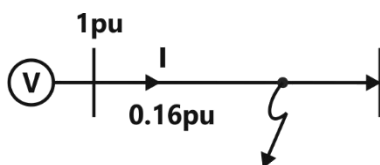
**10. Ans: (c)**

**Solution:**



If fault occurs at 80% of length

$$Z = 0.8 \times 0.2 = 0.16 \text{ pu}$$



$$I = \frac{1}{0.16} = 6.25 \text{ pu}$$

So, threshold current or minimum current is 6.25 pu

If fault occurs before 80% then impedance

is less, current is higher & it can be detected by relay



11. Consider a linear time-invariant system whose input  $r(t)$  and output  $y(t)$  are related by the following differential equation:

$$\frac{d^2 y(t)}{dt^2} + 4y(t) = 6r(t)$$

The poles of this system are at

- (a)  $+2, -2$  (b)  $+4j, -4j$   
 (c)  $+2j, -2j$  (d)  $+4, -4$

**Ans: (c)**

**Solution:**

$$\frac{d^2 y}{dt^2} + 4y = 6r(t)$$

Taking Laplace transform both sides

$$s^2 Y(s) + 4Y(s) = 6R(s)$$

$$\frac{Y(s)}{R(s)} = \frac{6}{s^2 + 4}$$

The poles of this transfer function are at

$$s^2 + 4 = 0$$

$$s = \pm 2j$$

12. A three-phase, 50 Hz, 4-pole induction motor runs at no-load with a slip of 1% with full load, the slip increases to 5%. The % speed regulation of the motor (rounded off to 2 decimal places) is \_\_\_\_\_.

**Ans: 4.1 to 4.3**

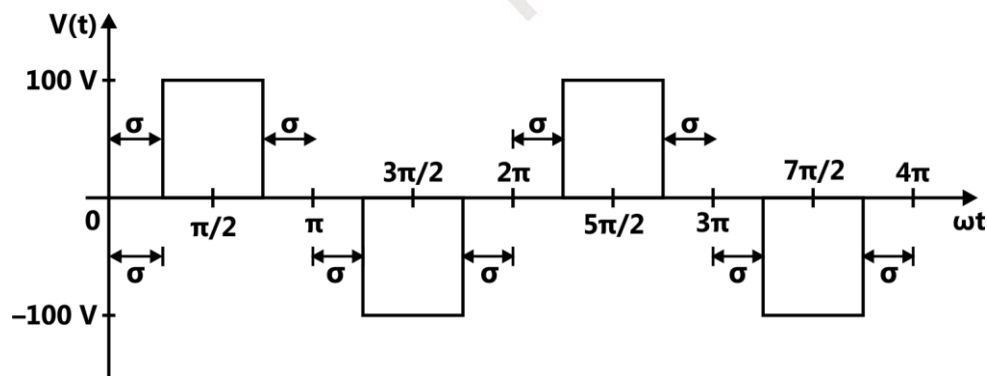
**Solution:**

$$n_{NL} = (1 - S_{NL})N_s = (1 - 0.01)N_s$$

$$n_{FL} = (1 - S_{FL})N_s = (1 - 0.05)N_s$$

$$\therefore \% \text{ slip}(s) = \frac{n_{NL} - n_{FL}}{n_{FL}} \times 100 = \frac{(1 - 0.01) - (1 - 0.05)}{(1 - 0.05)} \times 100 = 4.21\%$$

13. A single-phase inverter is fed from a 100 V dc source and is controlled using a quasi-square wave modulation scheme to produce an output waveform,  $v(t)$ , as shown. The angle  $\sigma$  is adjusted to entirely eliminate the 3<sup>rd</sup> harmonic component from the output voltage. Under this condition, for  $v(t)$ , the magnitude of the 5<sup>th</sup> harmonic component as a percentage of the magnitude of the fundamental component is \_\_\_\_\_ (rounded off to 2 decimal places).



**Ans: 20****Solution:**

The waveform for output voltage of inverter is based on single pulse modulation.

Fourier series of  $v(t)$

$$v(t) = \sum_{n=1}^{\infty} \frac{4 \times 100}{n\pi} \sin n d \sin \frac{\pi}{2} \sin n \omega_0 t$$

$$n = 1, 3, 5$$

$$\text{Where pulse width} = 2d = (\pi - 2\sigma)$$

To eliminate 3<sup>rd</sup> harmonic

$$\sin 3d = 0$$

$$\text{Or } 3d = 180^\circ$$

$$\text{Hence, } d = 60^\circ$$

$$V_5 = \frac{4 \times 100}{5\pi} \sin 5d \times \sin \frac{5\pi}{2}$$

$$V_1 = \frac{4 \times 100}{5\pi} \sin d \times \sin \frac{\pi}{2}$$

$$\frac{V_5}{V_1} = \frac{1}{5} \frac{\sin 300}{\sin 60} \times \frac{\sin \frac{5\pi}{2}}{\sin \frac{\pi}{2}}$$

$$\left| \frac{V_5}{V_1} \right| = \left| \frac{1}{5} \times \frac{\frac{\sqrt{3}}{2}}{\frac{\sqrt{3}}{2}} \right| = \frac{1}{5}$$

$$\left| \frac{V_5}{V_1} \right| = \left| \frac{1}{5} \times \frac{\frac{\sqrt{3}}{2}}{\frac{\sqrt{3}}{2}} \right| = \frac{1}{5}$$

$$\left| \frac{V_5}{V_1} \right| \times 100\% = 20\%$$

**14.** Which of the following statements is true about the two sided Laplace transform?

- (a) It has no poles for any bounded signal that is non-zero only inside a finite time interval.
- (b) The number of finite poles and finite zeroes must be equal.
- (c) If a signal can be expressed as a weighted sum of shifted one sided exponentials, then its Laplace Transform will have no poles.
- (d) It exists for every signal that may or may not have a Fourier transform.

**Ans: (a)**

**15.** Which of the following is true for all possible non-zero choices of integers  $m, n; m \neq n$ , or all possible non-zero choices of real numbers  $p, q; p \neq q$ , as applicable?

$$(a) \frac{1}{2\pi} \int_{-\pi/2}^{\pi/2} \sin p\theta \sin q\theta d\theta = 0$$

$$(b) \frac{1}{2\pi} \int_{-\pi}^{\pi} \sin p\theta \cos q\theta d\theta = 0$$

$$(c) \lim_{\alpha \rightarrow \infty} \frac{1}{2\alpha} \int_{-\alpha}^{\alpha} \sin p\theta \sin q\theta d\theta = 0$$

$$(d) \frac{1}{\pi} \int_0^{\pi} \sin m\theta \sin n\theta d\theta = 0$$

**Ans: (b)****Solution:**

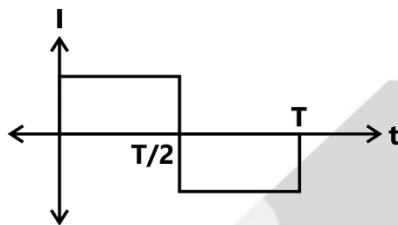
$$\frac{1}{2\pi} \int_{-\pi}^{\pi} \sin p\theta \cos q\theta d\theta = 0$$

**16.** A signal-phase, full-bridge diode rectifier fed from a 230 V, 50 Hz sinusoidal source supplies a series combination of finite resistance, R, and a very large inductance, L. The two most dominant frequency components in the source current are:

- (a) 150 Hz, 250 Hz                      (b) 50 Hz, 0 Hz  
(c) 50 Hz, 150 Hz                      (d) 50 Hz, 100 Hz

**Ans: (c)****Solution:**

The source current wave form for a single-phase full bridge rectifier is



A square wave has all odd harmonics present.

Hence, for fundamental frequency of 50Hz, two most dominant frequencies are,

$$f_0 \text{ and } 3f_0$$

$$\therefore 50 \text{ Hz and } \therefore 150 \text{ Hz}$$

**17.** A three-phase cylindrical rotor synchronous generator has a synchronous reactance  $X_s$  and a negligible armature resistance. The magnitude of per phase terminal voltage is  $V_A$  and the magnitude of per phase induced emf is  $E_A$  considering the following two statements, P and Q.

P: For any three-phase balanced leading load connected across the terminals of this synchronous generator,  $V_A$  is always more than  $E_A$

Q: For any three-phase balanced lagging load connected across the terminals of this synchronous generator,  $V_A$  is always less than  $E_A$

Which of the following options is correct?

- (a) P is true and Q is true                      (b) P is false and Q is true  
(c) P is false and Q is false                      (d) P is true and Q is false.

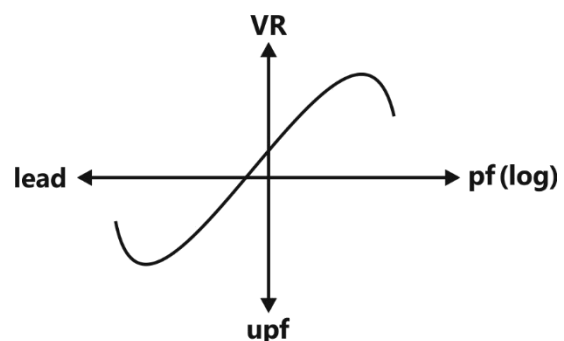
**Ans: (b)****Solution:**

$$\text{Voltage regulation of alternator} = \frac{E_A - V_A}{V_A} \times 100\%$$

The variation of voltage regulation with pf is as shown

For lightly leading load,  $VR > 0$  which means  $V_A < E_A$

Hence, P is false but Q is true



18. Consider a negative unity feedback system with forward path transfer function  $G(s) = \frac{K}{(s+a)(s-b)(s+c)}$ , where  $K, a, b, c$  are positive real numbers. For a Nyquist path enclosing the entire imaginary axis and right half of the  $s$ -plane in the clockwise direction, the Nyquist plot of  $(1+G(s))$ , encircles the origin of  $(1+G(s))$  - plane once in the clockwise direction and never passes through this origin for a certain value of  $K$ . Then, the number of poles of  $\frac{G(s)}{1+G(s)}$  lying in the open right half of the  $s$ -plane is \_\_\_\_\_.

Ans: 2

Solution:

$$N = P_+ - Z_+$$

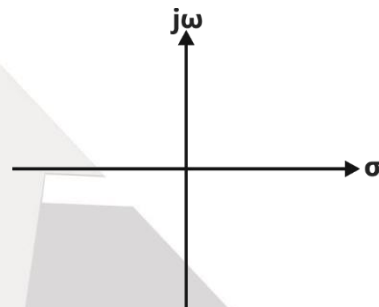
$N$  = No. of encirclement of  $(0, 0)$  in  $1+G(s)H(s)$  plane

$P_+$  = No. of poles of  $1+G(s)H(s)$  lying in RHP

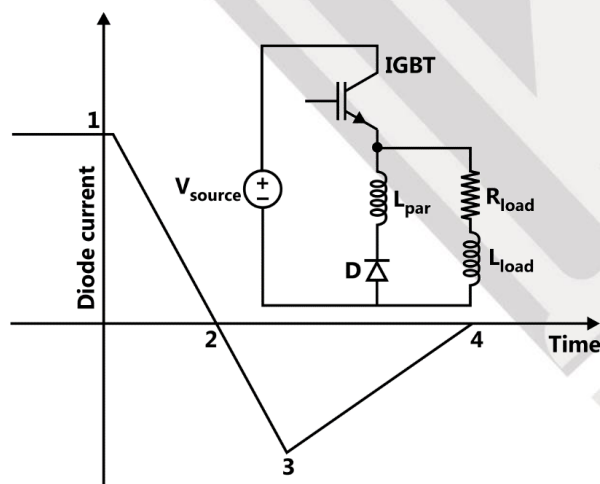
$Z_+$  = No. of zeros of  $1+G(s)H(s)$  lying in RHP

$$N = -1 = 1 - Z_+$$

$$Z_+ = 2$$



19. A double pulse measurement for an inductively loaded circuit controlled by the IGBT switch is carried out to evaluate the reverse recovery characteristics of the diode,  $D$ , represented approximately as a piecewise linear plot of current vs time at diode turn-off.  $L_{par}$  is a parasitic inductance due to the wiring of the circuit, and is in series with the diode. The point on the plot (indicate your choice by entering 1, 2, 3 or 4) at which the IGBT experiences the highest current stress is \_\_\_\_\_.



Ans: 3

Solution:

Assuming a highly inductive load

$$I_{LOAD} = \text{constant}$$

$$I_{IGBT} + I_{DIODE} = \text{constant}$$

$$\text{Hence, } I_{IGBT} = \text{constant} - I_{DIODE}$$

$$\text{So } I_{IGBT} = \text{constant} - I_{DIODE}$$

So  $I_{IGBT}$  is maximum when  $I_{DIODE}$  is minimum which corresponds to point 3 is

20. The value of the following complex integral, with  $c$  representing the unit circle centered at origin in the counterclockwise sense, is:

$$\oint_c \frac{z^2 + 1}{z^2 - 2z} dz$$

- (a)  $8\pi i$  (b)  $-8\pi i$   
(c)  $\pi i$  (d)  $-\pi i$

**Ans: (d)**

**Solution:**

$$I = \oint \frac{z^2 + 1}{z^2 - 2z}$$

These exists singularity at  $z = 0$  &  $z = 2$

But only  $z = 0$  lies in the region  $|z| \leq 1$

$\therefore$  Residue correspond to  $z = 0$

$$= \lim_{z \rightarrow 0} z \frac{z^2 + 1}{z(z - 2)} = -\frac{1}{2}$$

$$\therefore I = 2\pi i \times \left(-\frac{1}{2}\right) = -\pi i$$

21. A common-source amplifier with a drain resistance,  $R_D = 4.7k\Omega$  is powered using a  $10V$  power supply.

Assuming that the transconductance,  $g_m$ , is  $520\mu A/V$ , the voltage gain of the amplifier is closest to:

- (a) -1.22 (b) -2.44  
(c) 1.22 (d) 2.44

**Ans: (b)**

**Solution:**

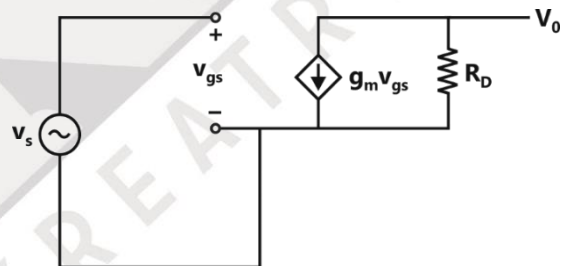
The small signals model of MOSFET common source amplifier is

$$V_o = -g_m V_{gs} R_D$$

By KVL,  $V_{gs} = V_s$

$$V_o = -g_m V_s R_D$$

$$\frac{V_o}{V_s} = -g_m R_D = -520 \times 10^{-6} \times 4700 = -2.44$$



22. A sequence detector is designed to detect precisely 3 digital inputs, with overlapping sequences detectable.

For the sequence  $(1, 0, 1)$  and input data  $(1, 1, 0, 1, 0, 0, 1, 1, 0, 1, 1, 0)$ , what is the output of this detector?

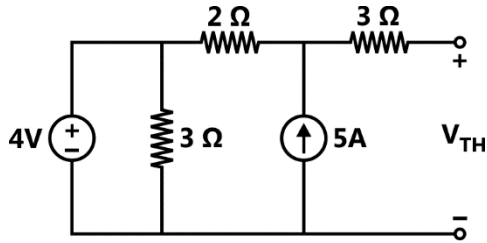
- (a)  $(0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0)$  (b)  $(1, 1, 0, 0, 0, 0, 1, 1, 0, 1, 0, 0)$   
(c)  $(0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0)$  (d)  $(0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 1, 0)$

**Ans: (c)**

**Solution:**

1 1 0 1 0 0 1 1 0 1 0 1

23. The Thevenin equivalent voltage,  $V_{TH}$ , in V (rounded off to 2 decimal places) of the network shown below, is \_\_\_\_\_.



**Ans: 14**

**Solution:**

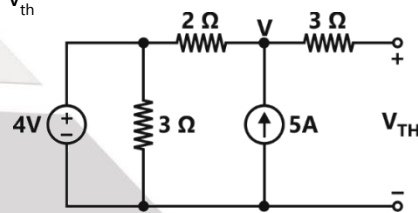
Due to open circuit, there is no current through  $3\Omega$  resistor with  $V_{th}$

Hence,  $V = V_{th}$

Apply KCL at V

$$\frac{V-4}{2} - 5 = 0$$

$$V = 14 \text{ V} = V_{th}$$



24.  $ax^3 + bx^2 + cx + d$  is a polynomial on real  $x$  over real coefficient  $a, b, c, d$  wherein  $a \neq 0$ . Which of the following statements is true?

- (a)  $d$  can be chosen to ensure that  $x = 0$  is a root for any given set  $a, b, c$ .
- (b)  $a, b, c, d$  can be chosen to ensure that all roots are complex.
- (c)  $c$  alone cannot ensure that all roots are real.
- (d) No choice of coefficients can make all roots identical

**Ans: (a)**

**Solution:**

For  $d = 0$

$$ax^3 + bx^2 + cx = 0$$

$$\text{or, } x = 0$$

25. A single-phase, 4kVA, 200V/100V, 50Hz transformer with laminated CRGO steel core has rated no-load loss of 450W. When the high-voltage winding is excited with 160V, 40Hz sinusoidal ac supply, the no-load losses are found to be 320W. When the high-voltage winding of the same transformer is supplied from a 100V, 25Hz sinusoidal ac source, the no-load losses will be \_\_\_\_\_ W (rounded off to 2 decimal places).

**Ans: 160 to 165**

**Solution:**

$$\text{As } \frac{V}{f} = \text{constant}$$

$$P_h \propto f, P_e \propto f^2$$

$$\therefore P_c = P_h + P_e = Af + Bf^2$$

Now;

$$\text{For } 200 \text{ V, } 50 \text{ Hz, } P_c = 450 \text{ W}$$

$$\text{For } 160 \text{ V, } 40 \text{ Hz, } P_c = 320 \text{ W}$$

$$\text{For } 100 \text{ V, } 25 \text{ Hz, } P_c = \text{Unknown}$$



$$\therefore 450 = 50A + (50)^2 B \quad \dots(i)$$

$$320 = 40A + (40)^2 B \quad \dots(ii)$$

Solving (i) and (ii),

$$A = 4, B = 0.1$$

$$\therefore P_c = 4 \times 25 + 0.1 \times (25)^2 \text{ at } f = 25 \text{ Hz} = 100 + 62.5$$

$$P_c = 162.5 \text{ W}$$

**26.** A non-ideal Si-based pn junction diode is tested by sweeping the bias applied across its terminals from  $-5\text{V}$  to  $+5\text{V}$ . The effective thermal voltage,  $V_T$ , for the diode is measured to be  $(29 \pm 2)\text{mV}$ . The resolution of the voltage source in the measurement range is  $1\text{mV}$ . The percentage uncertainty (rounded off to 2 decimal places) in the measured current at a bias voltage of  $0.02\text{V}$  is \_\_\_\_\_.

**Ans: 2.2 to 3.2**

**Solution:**

$$I = I_s \left( e^{\frac{V_D}{\eta V_T}} - 1 \right) \approx I_s e^{\frac{V_D}{\eta V_T}}$$

$$\frac{\partial I}{\partial V_D} = \frac{I_s e^{\frac{V_D}{\eta V_T}}}{\eta V_T} = \frac{I}{\eta V_T}$$

$$\frac{\partial I}{\partial V_T} = I_s e^{\frac{V_D}{\eta V_T}} \times \frac{-V_D}{\eta V_T^2} = \frac{-I V_D}{\eta V_T^2}$$

Uncertainty in I

$$\sigma_I = \left[ \left( \frac{\partial I}{\partial V_D} \right)^2 \sigma_{V_D}^2 + \left( \frac{\partial I}{\partial V_T} \right)^2 \sigma_{V_T}^2 \right]^{\frac{1}{2}}$$

$$\sigma_I = \left[ \frac{I^2}{\eta^2 V_T^2} \sigma_{V_D}^2 + \frac{I^2 V_D^2}{\eta^2 V_T^4} \sigma_{V_T}^2 \right]^{\frac{1}{2}}$$

% Uncertainty

$$\frac{\partial I}{I} \times 100 \left[ \frac{\sigma_{V_D}^2}{\eta^2 V_T^2} + \frac{\sigma_{V_T}^2}{\eta^2 V_T^4} V_D^2 \right]^{\frac{1}{2}} \times 100 = \left[ \frac{0.001}{2^2 \times 0.029^2} + \frac{0.002^2}{2^2 \times 0.029^4} \times 0.02 \right]^{\frac{1}{2}} \times 100 = 2.937\%$$

**27.** A single-phase, full-bridge, fully controlled thyristor rectifier feeds a load comprising a  $10\Omega$  resistance in series with a very large inductance. The rectifier is fed from an ideal  $230\text{V}$ ,  $50\text{Hz}$  sinusoidal source through cables which have negligible internal resistance and a total inductance of  $2.28\text{mH}$ . If the thyristors are triggered at an angle  $\alpha = 45^\circ$ , the commutation overlap angle in degree (rounded off to 2 decimal places) is \_\_\_\_\_.

**Ans: 2.3 to 2.7**

**Solution:**

$$\text{Total inductance from source} = 2L_s = 2.28\text{mH}$$

$$L_s = 1.14\text{mH}$$

Average output voltage



$$V_0 = \frac{2V_m}{\pi} \cos \alpha - 4fL_s I_0 = 2 \times \frac{230\sqrt{2}}{\pi} \cos 45 - 4 \times 50 \times 1.14 \times 10^{-3} \times I_0 = 146.422 - 0.228I_0$$

$$I_0 = \frac{V_0}{R}$$

$$V_0 = 146.422 - \frac{0.228}{10} \cdot V_0$$

$$V_0 = 143.158 \text{ V}$$

$$I_0 = 14.3158 \text{ A}$$

$$I_0 = \frac{V_m}{2\omega L_s} (\cos \alpha - \cos(\alpha + \mu))$$

$$\cos(\alpha + \mu) = 0.67558$$

$$\alpha + \mu = 47.5$$

$$\mu = 2.5^\circ$$

**28.** The vector function expressed by

$$\mathbf{F} = a_x (5y - k_1 z) + a_y (3z + k_2 x) + a_z (k_3 y - 4x)$$

represents a conservative field, where  $a_x, a_y, a_z$  are unit vectors along  $x, y$  and  $z$

directions, respectively. The values of constant  $k_1, k_2, k_3$  are given by

- (a)  $k_1 = 4, k_2 = 5, k_3 = 3$                       (b)  $k_1 = 3, k_2 = 8, k_3 = 5$   
 (c)  $k_1 = 0, k_2 = 0, k_3 = 0$                       (d)  $k_1 = 3, k_2 = 3, k_3 = 7$

**Ans: (a)**

**Solution:**

$$\mathbf{D} \times \mathbf{f} = 0$$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 5y - k_1 z & 3z + k_2 x & k_3 y - 4x \end{vmatrix} = 0$$

$$\Rightarrow \hat{i}(k_3 - 3) - \hat{j}(-4 + k_1) + \hat{k}(k_2 - 5) = 0$$

$$\Rightarrow k_3 - 3 = 0, k_1 - 4 = 0, k_2 - 5 = 0$$

$$k_1 = 4$$

$$k_2 = 5$$

$$k_3 = 3$$

**29.** A cylindrical rotor synchronous generator with constant real power output and constant terminal voltage is supplying 100 A current to a 0.9 lagging power factor load. An ideal reactor is now connected in parallel with the load, as a result of which the total lagging reactive power requirement of the load is twice the previous value while the real power remains unchanged. The armature current is now \_\_\_\_\_ A (rounded off to 2 decimal places)

**Ans: 123 to 127**

**Solution:**

$\therefore$  Active power is constant,

$$I_a \cos \phi = \text{constant}$$



$$\therefore I_{a_1} \cos \phi_1 = I_{a_2} \cos \phi_2 \quad \dots(i)$$

Now;

$$\cos \phi_1 = 0.9$$

$$\frac{Q}{P} = \tan \phi = 0.484$$

When Q doubles,

$$\tan \phi_2 = \frac{2Q}{P} = 0.9686$$

$$\cos \phi_2 = 0.7182$$

$$\therefore 100 \times 0.9 = I_{a_2} \times 0.7182$$

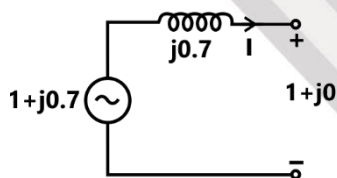
$$I_{a_2} = 125.29 \text{ A}$$

**30.** A cylindrical rotor synchronous generator has steady state synchronous reactance of  $0.7 \text{ pu}$  and subtransient reactance of  $0.2 \text{ pu}$ . It is operating at  $(1 + j0) \text{ pu}$  terminal voltage with an internal emf of  $(1 + j0.7) \text{ pu}$ . Following a three-phase solid short circuit fault at the terminal of the generator, the magnitude of the subtransient internal emf (rounded off to 2 decimal places) is \_\_\_\_\_ pu.

**Ans: 1.01 to 1.03**

**Solution:**

Before fault occurrence, system is



$$I = \frac{(1 + j0.7) - 1}{j0.7} = 1 \text{ pu}$$

when fault occurs, we place a source of prefault voltage  $(1 + j0)$  at fault point

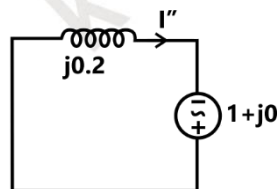
$$I'' = \frac{1 + j0}{j0.2} = -j5 \text{ pu}$$

$$\text{Fault current} = I + I'' = (1 - j5)$$

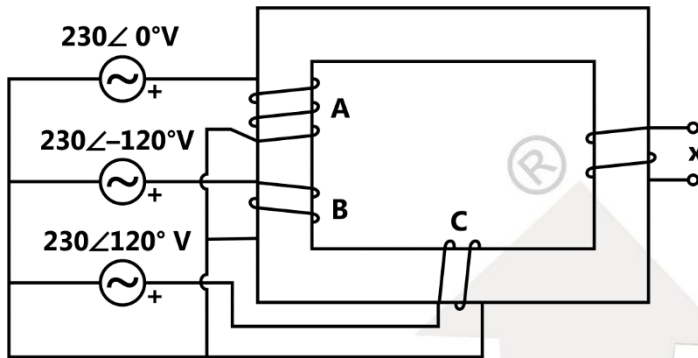
$$\text{Subtransient emf} = I_f \times x_d'' = (1 - j5) \times j0.2$$

$$E_f'' = (1 + j0.2)$$

$$|E_f''| = \sqrt{1 + 0.04} = 1.0198 \text{ pu}$$

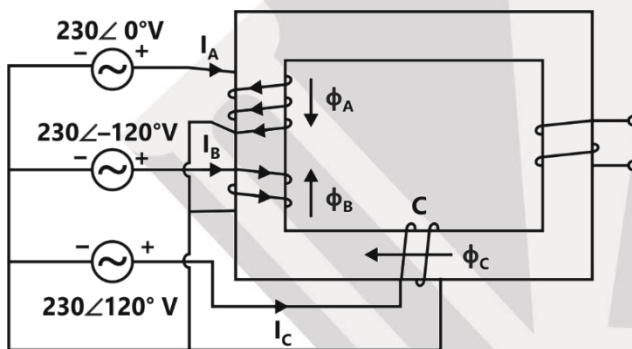


31. Windings 'A', 'B' and 'C' have 20 turns each and are wound on the same iron core as shown, along with winding 'X' which has 2 turns. The figure shows the sense (clockwise/anti-clockwise) of each of the windings only and does not reflect the exact number of turns. If windings 'A', 'B' and 'C' are supplied with balanced 3-phase voltages at 50 Hz and there is no core saturation, the no-load RMS voltage (in V, rounded off to 2 decimal places) across winding 'X' is \_\_\_\_\_.



Ans: 46

Solution:



Net flux inside the core =  $\phi_B + \phi_C - \phi_A$

$$\text{Voltage per turn} = \frac{V_B}{N_B} + \frac{V_C}{N_C} - \frac{V_A}{N_A} = \frac{230\angle-120}{20} + \frac{230\angle120}{20} - \frac{230\angle0}{20} = -23$$

Voltage across X =  $23 \times 2 = 46$  V

32. The static electric field inside a dielectric medium with relative permittivity,  $\epsilon_r = 2.25$ , expressed in cylindrical coordinate system is given by the following expression

$$\mathbf{E} = a_r 2r + a_\phi \left( \frac{3}{r} \right) + a_z 6$$

Where  $a_r$ ,  $a_\phi$ ,  $a_z$  are unit vectors along  $r$ ,  $\phi$  and  $z$  directions, respectively. If the above expression represents a valid electrostatic field inside the medium, then the volume charge density associated with this field in terms of free space permittivity,  $\epsilon_0$ , in SI units is given by:

- (a)  $3\epsilon_0$  (b)  $4\epsilon_0$   
(c)  $5\epsilon_0$  (d)  $9\epsilon_0$

**Ans: (d)**

**Solution:**

$$\vec{E} = 2r\hat{a}_r + \frac{3}{r}\hat{a}_\phi + 6\hat{a}_z$$

$$\epsilon = 2.25 \epsilon_0$$

$$\vec{V} \cdot \vec{D} = \rho_v$$

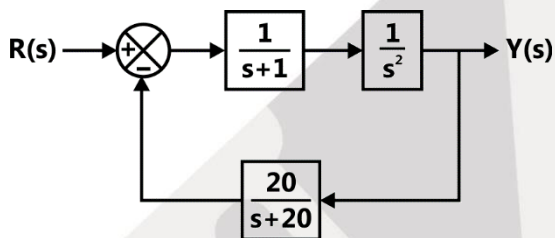
$$\frac{1}{\rho} \frac{\partial}{\partial \rho} [\rho \times 2\rho] + \frac{1}{\rho} \frac{\partial}{\partial \phi} \left[ \frac{3}{\rho} \right] + \frac{\partial}{\partial z} (6) = \frac{\rho_v}{\epsilon}$$

$$\frac{1}{\rho} 2 \times 2\rho = \frac{\rho_v}{\epsilon}$$

$$\rho_v = 4 \times 2.25 \epsilon_0$$

$$\rho_v = 9 \epsilon_0$$

**33.** Which of the following options is correct for the system shown below?



(a) 4<sup>th</sup> order and stable

(c) 3<sup>rd</sup> order and unstable

(b) 3<sup>rd</sup> order and stable

(d) 4<sup>th</sup> order and unstable

**Ans: (d)**

**Solution:**

$$G(s)H(s) = \frac{20}{s^2(s+1)(s+20)}$$

Characteristic equation is,

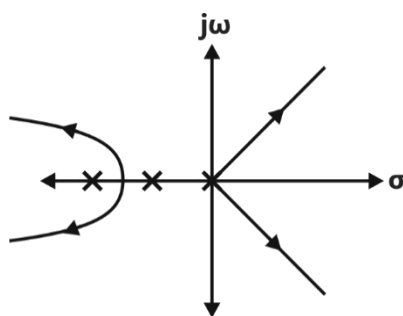
$$1 + G(s)H(s) = 0$$

$$\Rightarrow 1 + \frac{20}{s^2(s+1)(s+20)} = 0$$

$$\Rightarrow s^4 + 21s^3 + 20s^2 + 20 = 0$$

Hence, 4<sup>th</sup> order system

Now, drawing the root locus,



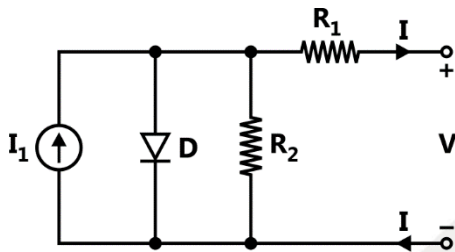
Hence; always there exist closed loop poles which are in the right half of s-plane.

Hence; system is unstable.



34. Consider the diode circuit shown below. The diode, D obeys the current-voltage characteristic  $I_D = I_S \left( \exp\left(\frac{V_D}{nV_T}\right) - 1 \right)$ , Where  $n > 1$ ,  $V_T > 0$ ,  $V_D$  is the voltage across the diode and  $I_D$  is the current through it.

The circuit is biased so that voltage,  $V > 0$  and current,  $I < 0$ . If you had to design this circuit to transfer maximum power from the current source ( $I_1$ ) to a resistive load (not shown) at the output, what values of  $R_1$  and  $R_2$  would you choose?

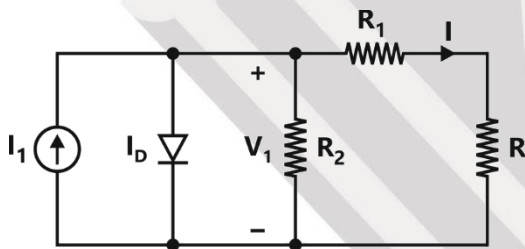


- (a) Large  $R_1$  and large  $R_2$       (b) Small  $R_1$  and large  $R_2$   
 (c) Small  $R_1$  and small  $R_2$       (d) Large  $R_1$  and small  $R_2$

**Ans: (b)**

**Solution:**

Since, circuit is biased such that  $V > 0$  &  $I < 0$  it implies the diode is forward biased. Connect a resistive load across terminals



Assume voltage across diode is  $V_1$

$$I = \left( I_1 - I_D - \frac{V_1}{R_2} \right) = I_1 - I_S \left( \exp\left(\frac{V_D}{nV_T}\right) - 1 \right) - \frac{V_1}{R_2}$$

To maximize  $I$ ,  $R_2$  should be large

$$\text{Similarly, } I = \frac{V_1}{R_1 + R}$$

To maximize  $I$ ,  $R_1$  should be small

35. Which of the following options is true for a linear time-invariant time system that obeys the difference equation:

$$y[n] - ay[n-1] = b_0x[n] - b_1x[n-1]$$

- (a) When  $x[n] = 0$ ,  $n < 0$ , the function  $y[n]$ ;  $n > 0$  is solely determined by the function  $x[n]$ .  
 (b) The system is necessarily causal.  
 (c)  $y[n]$  is unaffected by the values of  $x[n-k]$ ;  $k > 2$ .  
 (d) The system impulse response is non-zero at infinitely many instants.

**Ans: (b)****Solution:**

$$y[n] = ay[n-1] + b_0x[n] - b_1x[n-1]$$

So, present value of  $y[n]$  depends on present & past value of input & hence system causal

$y[n]$  is determined by input sequence  $x[n]$  & impulse response  $h[n]$

Put  $n = n-1$

$$y[n-1] = ay[n-2] + b_0x[n-2]$$

$$\text{Hence, } y[n] = a^2y[n-2] + ab_0x[n-1] - b_1x[n-1] + b_0x[n] - ab_0x[n-2]$$

So  $y[n]$  depends on  $x[n-2]$

If  $b_0 = 1, b_1 = 0$

$$y[n] - ay[n-1] = x[n] - ax[n-1]$$

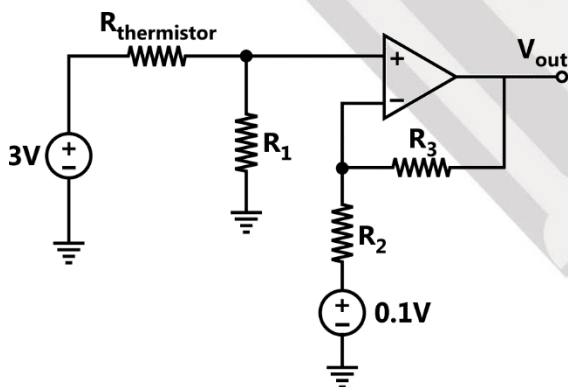
$$(1 - az^{-1})y(z) = (1 - az^{-1})x(z)$$

$$\frac{Y(z)}{X(z)} = 1 = H(z)$$

$$h[n] = \delta[n]$$

So,  $h[n]$  is non-zero at only one instant

**36.** The temperature of the coolant oil bath for a transformer is monitored using the circuit shown. It contains a thermistor with a temperature-dependent resistance,  $R_{\text{thermistor}} = 2(1 + \alpha T) \text{ k}\Omega$ , where  $T$  is the temperature in  $^{\circ}\text{C}$ . The temperature coefficient,  $\alpha$ , is  $-4(\pm 0.25)\% / ^{\circ}\text{C}$ . Circuit parameters:  $R_1 = 1 \text{ k}\Omega$ ,  $R_2 = 1.3 \text{ k}\Omega$ ,  $R_3 = 2.6 \text{ k}\Omega$ . The error in the output signal (in V, rounded off to 2 decimal places) at  $150^{\circ}\text{C}$  is \_\_\_\_\_.

**Ans: 0.07 to 0.09****Solution:**

Based on given circuit,

$$V_{\text{out}} = 3 \times \frac{R_1}{R_1 + R_T} \left( 1 + \frac{R_3}{R_2} \right) - 0.1 \times \frac{R_3}{R_1} = 3 \times \frac{1}{1 + R_T} \left( 1 + \frac{2.6}{1.3} \right) - 0.1 \times \frac{2.6}{1.3} = \frac{3 \times 3}{1 + R_T} - 0.2$$

$$- \left( \frac{9}{1 + R_T} - 0.2 \right)$$



$$R_T \text{ at } 150^\circ\text{C} = 2 \left( 1 - \frac{4}{100} \times 150 \right) = -10$$

$$V_0 = \frac{9}{1-10} - 0.2 = -1.2 \text{ V}$$

$$\text{if } \alpha = -(4 + 0.25)$$

$$R_T = 2 \left( 1 - \frac{4.25}{100} \times 150 \right) = -10.75$$

$$V_0 = -1.123, \text{ error} = 0.077 \text{ V}$$

$$\text{if } \alpha = -(4 - 0.25)$$

$$R_T = 2 \left( 1 - \frac{3.75}{100} \times 150 \right) = -9.25$$

$$V_0 = -1.29 \text{ error} = 0.09 \text{ V}$$

$$\text{Average error} = \frac{0.09 + 0.077}{2} = 0.083 \text{ V}$$

**37.** A stable real linear time-invariant system with single pole at  $p$ , has a transfer function  $H(s) = \frac{s^2 + 100}{s - p}$  with a

dc gain of 5. The smallest positive frequency, in rad/s, at unity gain is closest to:

- (a) 11.08 (b) 122.87  
(c) 78.13 (d) 8.84

**Ans: (d)**

**Solution:**

$$G(s)H(s) = \frac{s^2 + 100}{s - p}$$

$$\therefore \text{DC gain} = 5$$

$$\therefore \lim_{s \rightarrow 0} G(s)H(s) = 5$$

$$\therefore \frac{100}{-p} = 5$$

$$\Rightarrow p = -20$$

$$\therefore G(s)H(s) = \frac{s^2 + 100}{s + 20}$$

Now;

$$|G(j\omega)H(j\omega)| = 1$$

$$\Rightarrow \left| \frac{100 - \omega^2}{20 + j\omega} \right| = 1$$

$$\Rightarrow (100 - \omega^2)^2 = 20^2 + \omega^2$$

Solving we get,

$$\omega = 8.84 \text{ rad/s}$$

**38.** A resistor and a capacitor are connected in series to a 10V dc supply through a switch. The switch is closed at  $t=0$ , and the capacitor voltage is found to cross 0V at  $t = 0.4\tau$ , is the circuit time constant. The absolute value of percentage change required in the initial capacitor voltage if the zero crossing has to happen at  $t = 0.2\tau$  is \_\_\_\_\_ (rounded off to 2 decimal places).

**Ans: 53 to 57****Solution:**Let initial voltage across capacitor be  $V(0)$ Steady state voltage  $[V(\infty)] = 10V$ 

Voltage across capacitor;

$$V(t) = v(\infty) + [V(0) - V(\infty)]e^{-\frac{t}{\tau}}$$

$$\therefore V(t) = 10 + [V(0) - 10]e^{-\frac{t}{\tau}}$$

Now; for  $V(t) = 0$  at  $t = 0.4\tau$ 

$$0 = 10 + [V_1(0) - 10]e^{-\frac{0.4\tau}{\tau}}$$

$$\Rightarrow V_1(0) = -4.918 V$$

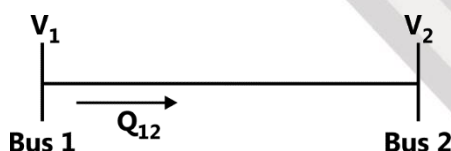
For  $v(t) = 0$  at  $t = 0.2\tau$ 

$$V(t) = 10 + (V_2(0) - 10)e^{-\frac{0.2\tau}{\tau}} = 0$$

$$\Rightarrow V_2(0) = -2.214$$

$$\% \text{ Change in initial capacitor voltage} = \frac{\Delta V(0)}{V_1(0)} \times 100 = \frac{4.918 - 2.214}{4.918} \times 100 = 54.989\%$$

**39.** Bus 1 with voltage magnitude  $V_1 = 1.1 \text{ pu}$  is sending reactive power  $Q_{12}$  towards bus 2 with voltage magnitude  $V_2 = 1 \text{ pu}$  through a lossless transmission line of reactance  $X$ . Keeping the voltage at bus 2 fixed at 1 pu, magnitude of voltage at bus 1 is changed, so that the reactive power  $Q_{12}$  sent from bus 1 is increased by 20%. Real power flow through the line under both the conditions is zero. The new value of the voltage magnitude,  $V_1$ , in pu (rounded off to 2 decimal places), at bus 1 is \_\_\_\_\_.

**Ans: 1.10 to 1.14****Solution:**Real power,  $P = 0$ 

$$P = \frac{V_1 V_2}{X} \sin \delta = 0$$

Therefore  $\delta = 0$ 

$$Q_{12} = \frac{V_1}{X} (V_1 - V_2 \cos \delta) = \frac{1.1}{X} (1.1 - 1 \times 1) = \frac{0.11}{X}$$

If  $Q_{12}$  is increased by 20%

$$Q_{12} = 1.2 \times \frac{0.11}{X} = \frac{0.132}{X}$$

$$Q_{12} = \frac{V_1}{X} (V_1 - V_2 \cos \delta)$$

Since, real power = 0,  $\delta = 0$

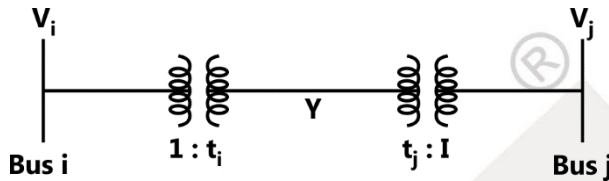


$$\frac{0.132}{X} = \frac{V_1}{X}(V_1 - 1)$$

$$V_1^2 - V_1 - 0.132 = 0 \Rightarrow V_1 = 1.118, -0.118$$

$$V_1 = 1.12 \text{ pu}$$

40. Two buses, i and j, are connected with a transmission line of admittance Y, at the two ends of which there are ideal transformers with turns ratios as shown. Bus admittance matrix for the system is:



$$(a) \begin{bmatrix} t_i^2 Y & -t_i t_j Y \\ -t_i t_j Y & t_j^2 Y \end{bmatrix}$$

$$(b) \begin{bmatrix} t_i^2 t_j Y & -t_j^2 Y \\ -t_i^2 Y & t_i t_j Y \end{bmatrix}$$

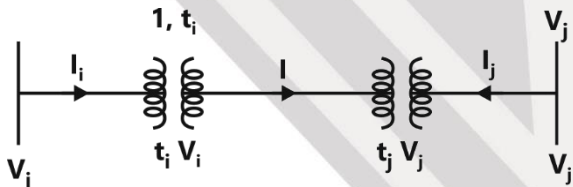
$$(c) \begin{bmatrix} t_i t_j Y & -(t_i - t_j)^2 Y \\ -(t_i - t_j)^2 Y & t_i t_j Y \end{bmatrix}$$

$$(d) \begin{bmatrix} -t_i t_j Y & t_j^2 Y \\ t_i^2 Y & -t_i t_j Y \end{bmatrix}$$

Ans: (a)

Solution:

Voltage across both ends of admittance is as shown



$$I = (t_i V_i - t_j V_j) Y$$

$$I_i = t_i I = t_i^2 Y V_i - t_i t_j Y V_j$$

$$I_j = -t_j I = -t_i t_j Y V_i + t_j^2 Y V_j$$

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} t_i^2 Y & -t_i t_j Y \\ -t_i t_j Y & t_j^2 Y \end{bmatrix} \begin{bmatrix} V_i \\ V_j \end{bmatrix}$$

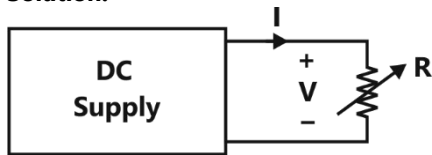
41. A benchtop dc power supply acts as an ideal 4A current as long as its terminal voltage is below 10V. Beyond this point, it begins to behave as an ideal 10V voltage source for all load currents going down to 0A. When connected to an ideal rheostat, find the load resistance value at which maximum power is transferred, and the corresponding load voltage and current.

(a)  $2.5\Omega, 10V$

(b)  $2.5\Omega, 5V$

(c) Open, 4A, 0A

(d) Short,  $\infty$  A, 10 V

**Ans: (a)****Solution:**

If supply acts as 4A current source

$$V = 4R, \quad D = 4^2 R$$

Since  $V_{\max} = 10V, R_{\max} = 2.5$

$$P_{\max} = 16 \times 2.5 = 40 \text{ W}$$

Now, if supply acts as 10 V source

$$I = \frac{10}{R} \quad P = \frac{10^2}{R}$$

This occurs for  $R > 2.5$

$$P_{\max} = \frac{10^2}{R_{\min}} = \frac{10^2}{2.5} = 40 \text{ W}$$

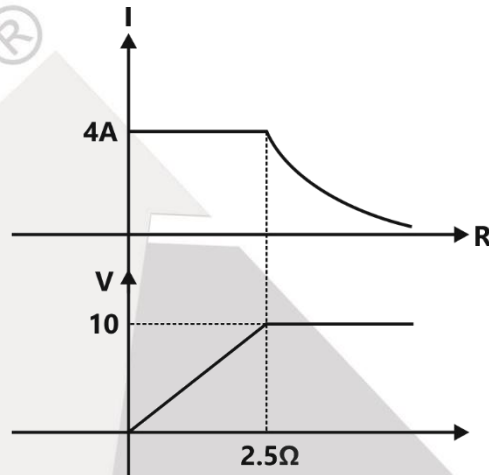
Hence,  $P_{\max} = 40 \text{ W}$

$$R = 2.5 \text{ W}$$

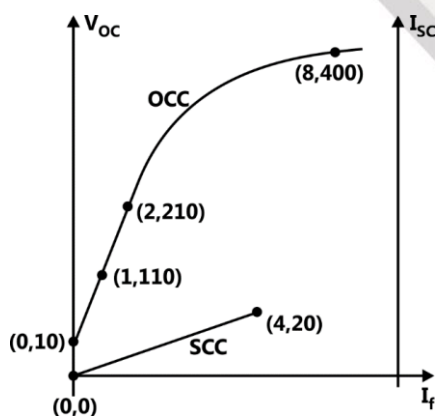
$$V = 10V$$

$$I = 4A$$

The characteristics of supply are as shown



**42.** The figure below shows the per-phase Open Circuit Characteristics (measured in V) and Short Circuit Characteristics (measured in A) of a 14kVA, 400V, 50Hz, 4-pole, 3-phase, delta connected alternator, driven at 1500 rpm. The field current,  $I_f$  is measured in A. Readings taken are marked as respective (x,y) coordinates in the figure. Ratio of the unsaturated and saturated synchronous impedance ( $Z_{s(\text{unsat})} / Z_{s(\text{sat})}$ ) of the alternator is closest to:



(a) 2.000

(c) 1.000

(b) 2.025

(d) 2.100

**Ans: (d)****Solution:**

For unsaturated synchronous impedance



$$Z_{s(\text{unsat})} = \frac{V_{oc}}{I_{sc}} = \frac{V_{oc}/I_f}{I_{sc}/I_f} = \frac{\text{slope of occ}}{\text{slope of scc}} = \frac{(210-110)/(2-1)}{(20-0)/(4-0)} = \frac{100}{5} = 20\Omega$$

For saturated synchronous impedance

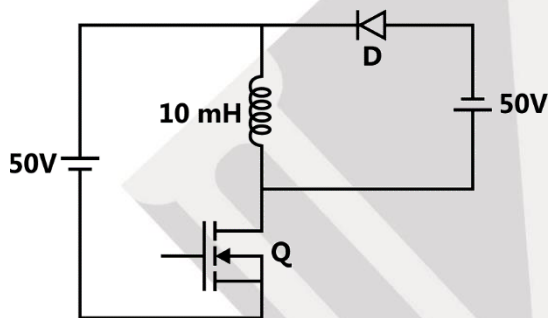
$$Z_{s(\text{sat})} = \frac{V_{oc}}{I_{sc}} \Big|_{I_f} = 8A$$

$$I_{sc} \text{ (at } I_f = 8A) = \text{slope} \times 8A = \frac{(20-0)}{(4-0)} \times 8 = 40A$$

$$Z_{s(\text{sat})} = \frac{400}{40} = 10\Omega$$

$$\frac{Z_{s(\text{unsat})}}{Z_{s(\text{sat})}} = \frac{20}{10} = 2$$

**43.** In the dc-dc converter circuit shown, switch Q is switched at a frequency of 10 kHz with a duty ratio of 0.6. All components of the circuit are ideal, and the initial current in the inductor is zero. Energy stored in the inductor in mJ (rounded off to 2 decimal places) at the end of 10 complete switching cycles is \_\_\_\_\_.



**Ans: 5**

**Solution:**

When switch is on,  $0 < t < 0.6T$

$$V_L = 50V$$

$$L \times \frac{di}{dt} = 50$$

If current rises from 0 to I

$$L \times \frac{I}{0.6T} = 50$$

$$I = \frac{30T}{L}$$

Now when switch is Off & diode is ON

$$0.6T < t < T$$

$$V_L = -50V$$

$$L \frac{di}{dt} = -50$$

Assume current falls from I to I'

$$L \frac{(I' - I)}{(T - 0.6T)} = -50$$

$$I' = I - \frac{20T}{L} = \frac{10T}{L}$$

Hence, net charging in 1 cycle =  $10 \frac{T}{L}$

in 10 cycle,  $i = \frac{100 T}{L}$

energy stored =  $\frac{1}{2} Li^2 = \frac{1}{2} \times \frac{10^4 \times T^2}{L}$

energy =  $\frac{1}{2} \times \frac{10^4}{f^2 L} = \frac{10^4}{2 \times (10^8) \times 10^{-2}} = \frac{10^{-4}}{2 \times 10^{-2}} = \frac{0.01}{2} = 5 \text{ mJ}$

**44.** Consider a permanent magnet dc (PMDC) motor which is initially at rest. At  $t = 0$ , a dc voltage of 5 V is applied to the motor. Its speed monotonically increases from 0 rad/s to 6.32 rad/s in 0.5 s and finally settles to 10 rad/s. Assuming that the armature inductance of the motor is negligible, the transfer function for the motor is

(a)  $\frac{10}{s+0.5}$

(b)  $\frac{10}{0.5s+1}$

(c)  $\frac{2}{0.5s+1}$

(d)  $\frac{2}{s+0.5}$

**Ans: (c)**

**Solution:**

Assuming that transfer function is  $= \frac{k}{1+sT}$

$$\frac{\omega(s)}{V(s)} = \frac{k}{1+sT}$$

$$V(t) = 5u(t)$$

$$V(s) = \frac{5}{s}$$

$$\omega(s) = \frac{k \times 5}{s(1+sT)}$$

$$\omega(\infty) = \lim_{s \rightarrow 0} s\omega(s) = 5k = 10$$

$$k = 2$$

$$\text{at } t = \tau, \omega = 63.2\% \text{ of } \omega(\infty)$$

$$t = \tau, \omega = 6.32 \text{ rad/sec}$$

$$\& \text{ hence } \tau = 0.5 \text{ sec}$$

$$T(s) = \frac{2}{0.5s+1}$$

**45.** Suppose for input  $x(t)$  a linear time-invariant system with impulse response  $h(t)$  produces output  $y(t)$ , so that  $x(t) * h(t) = y(t)$ . Further, if  $|x(t)| * |h(t)| = z(t)$ , which of the following statements is true?

(a) For all  $t \in (-\infty, \infty)$ ,  $z(t) \leq y(t)$

(b) For some but not all  $t \in (-\infty, \infty)$ ,  $z(t) \geq y(t)$

(c) For some but not all  $t \in (-\infty, \infty)$ ,  $z(t) \leq y(t)$

(d) For all  $t \in (-\infty, \infty)$ ,  $z(t) \geq y(t)$

**Ans: (d)****Solution:**

$$x(f) * h(f) = y(t) = \int_{-\infty}^t x(\tau) h(t - \tau) d\tau$$

$$|x(t)| * |h(t)| = z(t) = \int_{-\infty}^t |x(\tau)| |h(t - \tau)| d\tau$$

Using the property of definite integral,

$$\int_a^b |f_1 f_2| dx \leq \int_a^b |f_1| |f_2| dx$$

where  $f_1$  &  $f_2$  are functions of  $x$ 

Hence,

$$|x(t)| * |h(t)| \geq x(t) * h(t) \quad \forall t \in \mathbb{R}$$

$$\therefore z(t) \geq y(t) \text{ for every } -\infty < t < \infty$$

46. The number of purely real elements in a lower triangular representation of the given  $3 \times 3$  matrix, obtained through the given decomposition is \_\_\_\_\_.

$$\begin{bmatrix} 2 & 3 & 3 \\ 3 & 2 & 1 \\ 3 & 1 & 7 \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{12} & a_{22} & 0 \\ a_{13} & a_{23} & a_{33} \end{bmatrix}^T$$

(a) 5

(b) 6

(c) 8

(d) 9

**Ans: (b)****Solution:**

$$\begin{bmatrix} 2 & 3 & 3 \\ 3 & 2 & 1 \\ 3 & 1 & 7 \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{12} & a_{22} & 0 \\ a_{13} & a_{23} & a_{33} \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ 0 & a_{22} & a_{23} \\ 0 & 0 & a_{33} \end{bmatrix}$$

$$a_{11}^2 = 2 \rightarrow a_{11} = \sqrt{2}$$

$$a_{11}a_{12} = 3$$

$$a_{12} = \frac{3}{\sqrt{2}}$$

$$a_{11}a_{13} = 3$$

$$a_{13} = \frac{3}{\sqrt{2}}$$

$$a_{12}a_{12} + a_{22}a_{22} = 2$$

$$\frac{a}{2} + a_{22}^2 = 2$$

$$a_{22}^2 = 2 - \frac{9}{2} = -\frac{5}{2}$$

$$a_{22} = \sqrt{\frac{5}{2}}j$$

$$a_{13}a_{12} + a_{22}a_{23} = 1$$

$$\frac{9}{2} + \frac{\sqrt{5}}{2}j a_{23} = 1$$

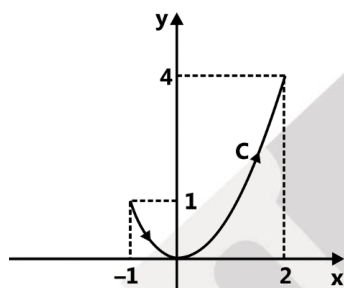
47. Let  $a_x$  and  $a_y$  be unit vectors along x and y directions, respectively. A vector function is given by

$$F = a_x y - a_y x$$

The line integral of the above function

$$\int_C F \cdot dl$$

Along the curve C, which follows the parabola  $y = x^2$  as shown below is \_\_\_\_\_ (rounded off to 2 decimal places).



Ans: -3

Solution

$$\vec{F} = y\hat{x} - x\hat{y}$$

$$y = x^2 \rightarrow dy = 2x dx$$

$$\int \vec{F} \cdot d\vec{l} = \int y dx - \int x dy = \int x^2 dx - \int x^2 x dx = \int_{-1}^2 x^2 dx - \left[ \frac{x^3}{3} \right]_{-1}^2 = \frac{-1}{3} [8 + 1] = -3$$

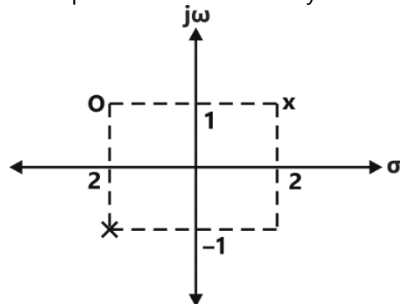
48. The causal realization of a system transfer function  $H(s)$  having poles at  $(2, -1)$ ,  $(-2, 1)$  and zeroes at  $(2, 1)$ ,  $(-2, -1)$  will be

- (a) Unstable, real, highpass (b) Stable, complex lowpass  
(c) Stable, real, allpass (d) Unstable, complex, allpass

Ans: (d)

Solution:

Since poles and zeroes are symmetrical about imaginary axis, it will be all pass.



Since there are complex poles on right half of s-plane, it is complex and unstable.



49. A 250 V dc shunt motor has an armature resistance of  $0.2 \Omega$  and a field resistance of  $100 \Omega$ . When the motor is operated on no-load at rated voltage, it draws an armature current of 5A and runs at 1200 rpm. When a load is coupled to the motor, it draws total line current of 50A at rated voltage, with a 5% reduction in the air-gap flux due to armature reaction. Voltage drop across the brushes can be taken as 1 V per brush under all operating conditions. The speed of the motor, in rpm, under this condition, is closest to:

- (a) 1000 (b) 1220  
(c) 900 (d) 1200

**Ans: (b)**

**Solution:**

at no-load,  $I_a = 5A$

$$E_a = 250 - 5 \times 0.2 - 2 = 247V$$

Under loaded condition,  $I_L = 50A$

$$I_f = \frac{V_t}{R_f} = \frac{250}{100} = 2.5A$$

$$I_a = I_L - I_f = 47.5A$$

$$E_2 = V_t - I_a R_a - V_{BD} = 250 - 47.5 \times 0.2 - 2 = 238.5V$$

$$\frac{E_2}{E_1} = \frac{\phi_2}{\phi_1} \times \frac{N_1}{N_2}$$

$$N_2 = \frac{E_2}{E_1} \times \frac{\phi_1}{\phi_2} \times N_1 = \frac{238.5}{247} \times \frac{1}{0.95} \times 1200 = 1220 \text{ rpm}$$

50. Let  $a_r$ ,  $a_\phi$  and  $a_z$  be unit vectors along  $r$ ,  $\phi$  and  $z$  directions, respectively in the cylindrical coordinate system.

For the electric flux density given by  $D = (a_r 15 + a_\phi 2r - a_z 3rz)$  Coulomb /  $m^2$ , The total electric flux, in Coulomb, emanating from the volume enclosed by a solid cylinder of radius 3m and height 5 m oriented along the  $z$ -axis with its base at the origin is:

- (a)  $180\pi$  (b)  $90\pi$   
(c)  $108\pi$  (d)  $54\pi$

**Ans: (a)**

**Solution:**

$$\vec{D} = 15\hat{a}_r + 2r\hat{a}_\phi - 3rz\hat{a}_z$$

$$\oiint \vec{D} \cdot d\vec{s} = \iiint (\nabla \cdot \vec{D}) dv$$

$$\nabla \cdot \vec{D} = \frac{1}{r} \frac{\partial}{\partial r} [r15] + \frac{1}{r} \frac{\partial}{\partial \phi} 2r + \frac{\partial}{\partial z} [-3rz]$$

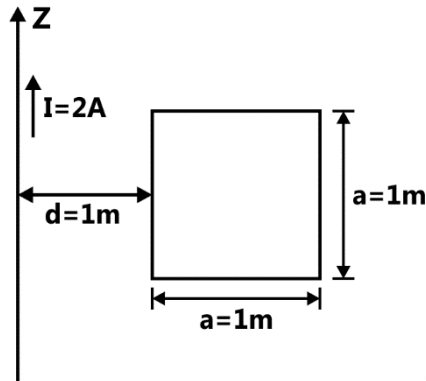
$$\Delta \cdot \vec{D} = -3r + \frac{15}{r}$$

$$\iiint -3rdrd\phi dz + \iiint 15drd\phi dz - 3 \left[ \frac{r^3}{3} \right]_0^3 [2\pi][5] + 15 \times 2\pi \times 3 \times 5$$

$$= -[27] \times 10\pi + 450\pi = 450\pi - 270\pi = 180\pi$$



51. A conducting square loop of side length 1 m is placed at a distance of 1 m from a long straight wire carrying a current  $I = 2\text{ A}$  as shown below. The mutual inductance, in nH (rounded off to 2 decimal places), between the conducting loop and the long wire is \_\_\_\_\_.



Ans: 136 to 143

Solution:

$$\vec{B} = \frac{\mu_0 I}{2\pi r}$$

$$d\phi = \vec{B} \cdot d\vec{A} = \frac{\mu_0 I}{2\pi(x+1)} \times dx$$

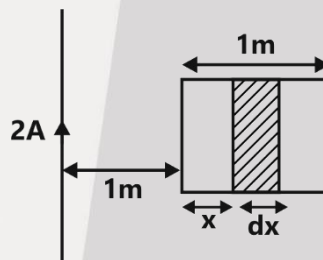
$$\therefore \phi = \frac{\mu_0 I}{2\pi} \int_1^2 \frac{dx}{1+x} = \frac{\mu_0 \times I}{2\pi} [\ln(1+x)]_1^2$$

$$\frac{4\pi \times I \times 10^{-7}}{2\pi} (\ln 2)$$

$$\frac{\phi}{I} = \frac{4\pi \times 10^{-7}}{2\pi} \ln 2 = 138.6 \text{ nH}$$

$$\therefore M = 138.6 \text{ nH}$$

$$[\because \phi = MI]$$



52. A non-ideal diode is biased with a voltage of  $-0.03\text{ V}$ , and a diode current of  $I_1$  is measured. The thermal voltage is  $26\text{ mV}$  and the ideality factor for the diode is  $15/13$ . The voltage, in V, at which the measured current increases to  $1.5I_1$  is closest to:

- (a)  $-0.09$  (b)  $-1.50$   
(c)  $-4.50$  (d)  $-0.02$

Ans: (a)

Solution:

$$\eta = \frac{15}{13}, V_T = 26 \text{ mV}$$

$$V_{D_1} = -0.03\text{ V} = -30 \text{ mV}$$

$$I_{D_2} = 1.5 I_{D_1}$$

$$\Rightarrow I_s \left( e^{\frac{V_{D_2}}{\eta V_T}} - 1 \right) = I_s \left( e^{\frac{V_{D_1}}{\eta V_T}} - 1 \right) \times 1.5$$



$$\Rightarrow 1.5 \left( \frac{V_{D_2}}{e^{\frac{15}{13} \times 26}} \right) = e^{\frac{-30}{13}} + 0.5$$

$$V_{D_2} \approx -0.09 \text{ V}$$

**53.** An 8085 microprocessor accesses two memory locations (2001H) and (2002H), that contain 8-bit numbers 98H, and B1H, respectively. The following program is executed:

```
LXI H, 2001H
MVI A, 21H
INX H
ADD M
INX H
MOV M, A
HLT
```

At the end of this program, the memory location 2003H contains the number in decimal (base 10) form \_\_\_\_\_.

**Ans: 210**

**Solution:**

```
LXI H, 2001H ,    HL → 2001H
MVI A, 21H      ,    A → 21H
INX H           ,    HL → 2002H
ADD M           ,    A → 21 + data (2002H) = 21 + B1 = (D2)
INX H           ,    H → 2003H
MOV M, A       ,    2003H ← D2H
HLT
```

$$\text{Memory} = D2 = 13 \times 16 + 2 = (210)_{10}$$

**54.** Consider a negative unity feedback system with the forward path transfer function  $\frac{s^2 + s + 1}{s^3 + 2s^2 + 2s + K}$ , where K is a positive real number. The value of K for which the system will have some of its poles on the imaginary axis is \_\_\_\_\_.

- (a) 6 (b) 9  
(c) 8 (d) 7

**Ans: (c)**

**Solution:**

$$s^3 + 3s^2 + 3s + 1 + k = 0$$

$$1 + k = 9$$

$$k = 8$$

**55.** For real numbers, x and y, with  $y = 3x^2 + 3x + 1$ , the maximum and minimum value of y for  $x \in [-2, 0]$  are respectively, \_\_\_\_\_.

- (a) 1 and 1/4 (b) -2 and -1/2  
(c) 7 and 1/4 (d) 7 and 1

**Ans: (c)****Solution:**

$$y = 3x^2 + 3x + 1 \quad x \in [-2, 0]$$

$$\frac{dy}{dx} = 6x + 3 = 0$$

$$x = -\frac{1}{2}$$

$$Y(-2) = 12 - 6 + 1 = 7$$

$$Y(0) = 1$$

$$Y\left(-\frac{1}{2}\right) = 3 \times \frac{1}{4} - \frac{3}{2} + 1 = \frac{3}{4} + 1 - \frac{3}{2} = \frac{7}{4} - \frac{3}{2} = \frac{1}{4}$$

Maximum value = 7

Minimum value =  $\frac{1}{4}$

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